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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 883
Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C. ▼ September 20, 1920

EXPERIMENTS WITH FLAX ON BREAKING

By

CHARLES H. CLARK, formerly Assistant Agronomist in Charge of Flax Investigations, Office of Cereal Investigations

CONTENTS

	Page
Flax as a Sod Crop	1
The Present Flax Area	2
The Northern Great Plains Field Station and the Surrounding District	4
Scope of the Experiments	8
Experimental Methods	8
Size and Arrangement of Plats and Rows	9
Preparation of the Land	10
Interpretation of Experimental Results	11
Flax Experiments in Plats	11
Flax Experiments in Nursery Rows	22
Summary	29

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CONTENTS

Page.

Flax as a sod crop 1
The present flax area 2
  Extent 2
  Variations in soil 3
  Variations in climate 3
  The place of flax in the agriculture of the flax-producing States 3
The Northern Great Plains Field Station and the surrounding district 4
  Location 4
  History 4
  Topography 4
  Soils 4
  Native vegetation 5
  Climate 5
Scope of the experiments 8

Page.

Experimental methods 8
Size and arrangement of plats and rows 9
Preparation of the land 10
Interpretation of experimental results 11
Flax experiments in plats 11
  History and description of varieties 11
  Agronomic results 13
  Analytical results 17
  Rate-of-seeding experiments 21
  Date-of-seeding experiments 21
Flax experiments in nursery rows 22
  Source and variability of material 22
  Descriptive key to varieties 24
  Discussion of varieties by groups 25
Summary 27

FLAX AS A SOD CROP.

For 128 years flax has been grown in the United States, principally for its seed. The invention of the cotton gin in 1792 and the consequent cheap production of cotton fiber practically ended the flax-fiber industry in this country. From that date flax ceased to be a crop vital to the daily needs of each family and community. Its culture on the farms of New England and the other Eastern States was soon discontinued. Since then it has been a cash crop grown on a large sale in areas where distance from markets and poor transportation facilities called for a crop which possessed the greatest value per unit of bulk when marketed. The hardiness of the flax crop also made it popular in newly settled areas where poorly prepared seed beds were the rule.

From 1850 to 1860 half the flaxseed crop of the country was produced in Ohio and Kentucky. By 1902 North Dakota led all other States in the production of flaxseed. In the intervening years flax had followed the tide of development westward, State by State. Its reputation as the favorite sod crop of this area was firmly established. In 1918 fully 80 per cent of the crop was produced on breaking in the four principal flax-producing States. While conditions have changed and are changing annually in such a way as to emphasize the importance of flax culture under new and different methods of production, it is still as a sod crop that flax claims its right to a place in the agriculture of the North-Central States. This condition will persist probably for some years to come.

Although flax is grown principally on new land and is one of the most important crops in recently settled districts, no report of experiments conducted on breaking to determine the best adapted varieties or the cultural methods giving the most profitable return has yet been published in the United States.

Experiments with flax were started at the Northern Great Plains Field Station,[1] Mandan, N. Dak., in 1914, when land was first being broken for crops. This gave the opportunity to obtain three years' consecutive results with flax on breaking under almost uniform soil conditions. An experiment station could not have been selected more nearly in the geographical center of present seed-flax production.

This bulletin presents a discussion of varietal experiments in plats and nursery rows, covering both the present commercial varieties and various new introductions from other flax-producing countries. Agronomic and chemical data showing the differences in these varieties and strains are presented, together with the results of experiments in dates and rates of seeding in these three years.

THE PRESENT FLAX AREA.

EXTENT.

Flax is grown principally in the four States of North Dakota, Montana, Minnesota, and South Dakota, named in the order of their importance. Kansas, Iowa, Missouri, Nebraska, and Wyoming, with limited acreage, come next in relative importance in flax production, and Colorado, Idaho, and Oregon produce some flax, though statistics on their production usually are lacking.

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[1] The Northern Great Plains Field Station, Mandan, N. Dak., where the investigations herein reported were made, is a field station of the Bureau of Plant Industry, under the immediate supervision of the Office of Dry-Land Agriculture. The writer wishes gratefully to acknowledge the cooperation in these studies on the part of that office and particularly the help rendered from time to time by different members of the station staff. To Mr. J. T. Sarvis, assistant in dry-land agriculture, in charge of the agronomic work at the station, Mr. W. A. Peterson, former superintendent, and Mr. Arthur Shultz, former assistant in dry-land agriculture, the writer is particularly indebted. The assistance of Mr. John C. Brinsmade, jr., who had charge of the field experiments with flax at Mandan since May, 1916, is also gladly acknowledged.

VARIATIONS IN SOIL.

In the eastern portion of the flax area the soils are of glacial origin. The types range from light sand and sandy loam through clay loams of various descriptions, to muck and peat. Then come the transition soils found in North Dakota and South Dakota at the western edge of the glaciated area and the true residual and water-transported soils found in western North Dakota, western South Dakota, Montana, and other foothill and mountain States.

VARIATIONS IN CLIMATE.

Rainfall is the most essential factor in any consideration of climate in relation to flax production. The annual precipitation varies from 40 to 15 inches and less, but where flax is principally produced, the success of the crop usually is dependent upon the seasonal precipitation. This averages from 70 to 80 per cent of the annual precipitation in the important flax-producing States. In western North Dakota, western South Dakota, and Montana the seasonal precipitation is so limited that a favorable distribution is almost essential for maximum production. In eastern North Dakota, eastern South Dakota, Minnesota, and farther east not only rainfall but the general cloudiness and humidity are such that fiber flax of fair to good quality could be produced if labor and marketing conditions permitted. In the semiarid districts the general dryness of the atmosphere, with alternating periods of adequate moisture and drought, tends to produce brittle straw of uneven tensile strength and poorly adapted for fiber production. It is under these conditions that the bulk of the seed-flax crop is grown. Yield of seed, therefore, determines the fitness of any flax variety or method of culture.

THE PLACE OF FLAX IN THE AGRICULTURE OF THE FLAX-PRODUCING STATES.

In Iowa, Missouri, Wisconsin, and Minnesota flax is grown as a late catch crop on low wet lands which can not be prepared until late in the season or on reclaimed or sod land, and in some cases as a nurse crop for grasses, clover, or alfalfa. The acreage in these States is small. In eastern North Dakota the development of wilt-resistant varieties has encouraged the continuance of flax growing on a larger scale, where flax is used with grain crops in a more or less definite crop rotation. The present flax prices, if maintained, will insure the retention of the crop on farms in longer settled districts where new land can not be had. The results of the present study do not apply directly, however, to these conditions.

In practically all the area lying west of the ninety-eighth meridian flax is grown as the first crop on breaking, and the results obtained in the experiments at Mandan herein described apply directly to it. Moreover, these results agree very closely with those obtained under similar conditions at other stations located in this area.

THE NORTHERN GREAT PLAINS FIELD STATION AND THE SURROUNDING DISTRICT.

LOCATION.

The Northern Great Plains Field Station was located by the Office of Dry-Land Agriculture in the summer of 1913 2 miles southwest of Mandan, N. Dak., on the table-lands just west of the Missouri River and south of the Heart River.

HISTORY.

The station is located about 4 miles west of the site of old Fort Lincoln, which originally was on the west bank of the Missouri. The old Deadwood-Mandan trail runs across the station farm. Some of the 1916 flax plats were located across this old trail.

In this immediate vicinity, on the banks of the Missouri, the early Mandan Indians developed an agriculture admirably adapted to the district and produced varieties of corn and beans better suited to the local conditions than most of the more recent introductions. After the conquest of the Indians, the country was utilized for many years by cattlemen who grazed large herds of cattle on the free range of western South Dakota, western North Dakota, and Montana. More recently the country has been settled by homesteaders, many of whom have remained on their homesteads while others have let their lands lie uncultivated or have sold to men with more capital or more determination who have worked out successfully the problem of farming under semiarid conditions. Much of this land was granted to the transcontinental railroads, and a large acreage of tillable land still remains untouched by the plow.

TOPOGRAPHY.

The altitude at Mandan is 1,644 feet. The table-land or bench land on which the station is located is about 100 feet higher and is representative of most of the prairie west of the Missouri River. The whole district is known locally as the slope country. It varies from slightly to extremely rolling and rises rapidly to the westward. Its western extremity is crossed by the Bad Lands of western North Dakota and Montana and the Black Hills of South Dakota.

SOILS.

The soils at Mandan are all classified in the Williams loam series. They have been derived by the grinding and commingling of rocks through glacial action and constitute the predominating soil formation in North Dakota. These loams, while of moderately heavy texture and compact structure, are friable, easily cultivated, and maintain a good condition of tilth. Rains are readily absorbed except on steep slopes, and with the exception of limited areas in which the gravel content is high the subsoils are retentive of moisture.

West of the Missouri River this soil formation grades imperceptibly into the residual Morton loams of southwestern North Dakota and constitutes a transition type from the glacial soils of the eastern to the nonglacial or residual soils of the southwestern portion of the State. The Fargo loam series comprises glacial clays deposited in the old glacial Lake Agassiz, known more commonly as the Red River valley.

The soil of the station farm is of glacial origin. The table-land upon which most of the agronomic work is conducted and where the three years' experiments with flax were made is a post-glacial terrace with a uniformly level surface. The surface soil is a sandy black loam with a subsoil of medium heavy yellow clay, fine sand, and gravel.

NATIVE VEGETATION.

The native vegetation of this region has been carefully studied by Mr. J. T. Sarvis. A brief quotation from one of his recent papers admirably sums up his conclusions as follows:[1]

> From actual determinations in the field the percentages of short-grass and long-grass cover have been found to be nearly equal, so that the formation could be put in either class, according to the viewpoint of the observer. If the secondary plant layer is considered as the determining factor, the region falls in the long-grass formation. The vegetation in this particular area might be considered as in a transition zone, since the dominating species are typical of both formations.
>
> The dominating species are *Bouteloua gracilis* (*B. oligostachya*) and *Stipa comata*, * * * which is a typical long-grass species. This association is dominated by the Bouteloua. Sarvis [1916] has described in a paper other sections of western North Dakota which show the same dominating species.

CLIMATE.

Climatic observations were begun at Mandan with the establishment of the station in 1913. In addition to these, however, 40 years' continuous records of the Weather Bureau at Bismarck, 5 miles east of Mandan, are available. In the following paragraph Mr. Sarvis[2] has briefly summarized these data in such a way as to show clearly the general climatic conditions found in this section:

> Forty years' continuous records of the Weather Bureau at Bismarck are available for study. Observations were begun at the Mandan station during 1913. From 1875 to 1914, inclusive, or 40 years, the mean annual precipitation was 17. 41 inches. From 1875 to 1908, or 34 years, the average hourly wind velocity was 10 miles; the mean temperature 40°, maximum 106°, minimum −44° F.; the prevailing wind direction for each month in the year was northwest. The average date of the last killing frost in spring was May 11, the first in autumn September 17, the earliest in fall August 23, the latest in spring June 7, for the 34-year period. The records since do not materially change these figures.

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[1] Sarvis, J. T. Composition and density of the native vegetation in the vicinity of the Northern Great Plains Field Station. *In* Jour. Agr. Research, v. 19, no. 2, p. 63–72. 1920.

[2] Sarvis, J. T. Unpublished annual report of the agronomic experiments at Mandan, 1917. Copies on file in the Office of Dry-Land Agriculture, United States Department of Agriculture, Washington, D. C., at the Northern Great Plains Field Station, and at the North Dakota Agricultural Experiment Station, Agricultural College, N. Dak.

Precipitation summary.

	Inches.
Mean annual	17.41
Mean seasonal (April to July, inclusive)	9.91
Mean seasonal (April to August, inclusive)	11.91
Greatest seasonal (April to July, 1915, inclusive)	18.89
Greatest seasonal (April to August, 1915, inclusive)	19.52
Lowest seasonal (April to July, 1900, inclusive)	5.30
Lowest seasonal (April to August, 1894, inclusive)	6.65
Greatest annual (in 1876)	30.92
Lowest annual (in 1889)	11.03
Greatest in a single month to date (June, 1914)	10.68

The conditions just outlined are fairly representative of those obtaining in western North Dakota and western South Dakota. Westward, the rainfall gradually becomes less, until in Montana the average rainfall diminishes to 15 inches or less, with the exception of favored valleys.

Favorable climatic conditions for maximum plant development continued throughout the three years of the experiments herein recorded. Annual and seasonal average figures for certain climatic data in these years are given in Table I.

TABLE I.—*Annual and seasonal temperatures, total precipitation, total evaporation, and average wind velocity at the Northern Great Plains Field Station, Mandan, N. Dak., during 1914, 1915, and 1916.*

Year.	Annual data.					Seasonal data (April 1 to August 31).					
	Average temperature.			Precipitation.	Average wind velocity.	Average temperature.			Precipitation.	Evaporation.	Average wind velocity.
	Mean.	Maximum.	Minimum.			Mean.	Maximum.	Minimum.			
	°F.	*°F.*	*°F.*	*Inches.*	*Miles per hr.*	*°F.*	*°F.*	*°F.*	*Inches.*	*Inches.*	*Miles per hr.*
1914	42	54	30	23.87	6.3	60	72	48	19.04	28.894	6.2
1915	41	52	31	24.06	4.9	58	68	47	19.52	24.969	6.1
1916	39	50	26	15.07	6.1	59	71	48	10.46	26.877	6.2
Average	41	52	29	21.00	5.8	59	70	48	16.34	26.913	6.2

TEMPERATURE.

In 1914 both the annual and seasonal temperatures were slightly higher than normal. This, combined with plentiful moisture, produced a maximum crop growth. The crops also ripened early and in excellent shape. In 1915 the annual average minimum temperature was slightly above normal. During the summer months, however, cool, cloudy weather was the general rule, and the average mean, maximum, and minimum seasonal temperatures were all below normal. This resulted in a long growing season; in fact, if the first killing frost had not been delayed until October 6, making a frost-free period of 142 days as compared with an average of 129 days, much damage would have resulted from immaturity. In 1916 more nearly normal temperatures prevailed and crops developed and matured more normally.

PRECIPITATION.

The seasons of 1914 and 1915 were unusually rainy. While higher annual precipitations are on record for this area, the seasonal (April 1 to August 31) precipitation in 1915, 19.52 inches, is the highest recorded, while the precipitation of 10.68 inches in June, 1914, is the highest on record for any single month in the 43 years. At no time in either season was there any lack of moisture, while the cool, cloudy weather of August, 1915, delayed ripening almost a month. In 1916 the annual precipitation was 2.34 inches below the 40-year mean, while the seasonal was 1.45 inches below the mean seasonal. Fair distribution with abundant subsoil moisture matured satisfactory crops, although the yields were not as large as in the two previous seasons. Table II shows the precipitation for these years by months in comparison with the 40-year average.

TABLE II.—*Precipitation, at Mandan, N. Dak., for the years 1914, 1915, and 1916 compared with the 40-year average at Bismarck, N. Dak., from 1874 to 1913, inclusive.*

Period and year.	Precipitation (inches).												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
40-year average	0.53	0.49	1.01	1.69	2.44	3.62	2.15	2.00	1.29	1.01	0.61	0.57	17.41
1914	.07	.05	1.89	1.55	3.57	10.68	1.35	1.89	1.24	.90	.31	.37	23.87
1915	.07	T[1]	.30	1.11	4.98	6.32	6.48	.63	1.84	1.85	.34	.14	24.06
1916	.28	.09	1.88	.93	1.69	2.25	3.55	2.04	.92	.27	.07	1.10	15.07

[1] T=trace.

EVAPORATION.

Evaporation was high in 1914, as the result of a combination of high temperature and relatively high wind velocity. In 1915 the evaporation was far below the 3-year average, owing to the cool, cloudy weeks of August and September. In 1916 a drier atmosphere combined with higher temperatures resulted in an increased evaporation compared with that of 1915. The average mean and maximum temperatures were lower than in 1914, and this appears to have resulted in holding evaporation below the record in that year. This was fortunate, for the crops were several times in danger of being dried too quickly at critical stages in their development.

WIND.

Hot, drying winds of two and three days' duration occurred in July and August in both 1914 and 1916. In 1914 little damage was done, because of adequate moisture. The yields in 1916 doubtless were reduced somewhat because of premature ripening. Little difference in the seasonal average wind velocity is apparent, although the average annual for 1915 is below the 3-year average.

SCOPE OF THE EXPERIMENTS.

The flax studies at Mandan in the years 1914, 1915, and 1916 consisted of plat and nursery-row experiments with flax varieties, selections, hybrids, and new introductions and experiments with different dates and rates of seeding. Experiments with continuous cropping also were carried on, but these do not come within the scope of the present paper. In 1914 there were 44 plats and 217 nursery rows. A change in the size and arrangement of plats and rows in 1915 and additional studies increased these to 98 plats and 877 rows, while in 1916 a total of 148 plats and 2,090 nursery rows was included in the experiments. For the three years, 290 plats and 3,184 nursery rows were devoted to experiments with flax.

In addition to the agronomic studies, samples of seed from the varietal experiments in plats and from some of the varieties grown in nursery rows were analyzed for their oil content and the nature of the oils produced.[1]

EXPERIMENTAL METHODS.

The experiments with flax at Mandan were conducted with the following aims in view: (1) To determine the varieties best adapted to the semiarid conditions prevailing in the northern Great Plains area; (2) to obtain, through new importations, pure-line selection of superior adapted varieties, and the crossing of different varieties, strains with higher yielding possibilities, more resistant to disease, and with distinctive characters which would better enable purchasers and growers to insure against admixture and the substitution of inferior varieties; (3) to study certain problems in the inheritance of different characters of the flax plant; (4) to classify the cultivated flax varieties which are grown commercially for seed; and (5) to determine the best cultural practices for the area, including rates and dates of seeding.

Such a diversity of aims called for considerable variation in the size and arrangement of the plats and nursery rows. Occasionally, first-generation hybrids were grown in the greenhouse at Arlington Farm, near Washington, D. C., to save a year's time, but otherwise all experiments were conducted in the field. In 1916, a hail screen was provided for some of the hybrid material, but its use was not found practicable from the cultural point of view. Agronomic notes were taken on the varieties grown in plats and nursery, while more technical observations have been necessary in the breeding and classification studies.

The results of experiments in breeding and selection are not presented herein. Those experiments were begun in 1914 and have not progressed to the point where the results warrant presentation. However, data on certain varieties and new introductions grown in the nursery for three years are included, in order to show the possible value of varieties imported from various foreign countries for growing in the region under discussion.

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[1] The chemical analyses reported in this bulletin were obtained from studies conducted in cooperation with the Office of Drug, Poisonous, and Oil Plant Investigations. The writer wishes to express his thanks to Mr. Frank Rabak, of that office, under whose direct supervision the analyses were made.

SIZE AND ARRANGEMENT OF PLATS AND ROWS.

In 1914 all varietal and cultural experiments were seeded in twentieth-acre plats and the series duplicated (fig. 1). In 1915 the varieties were seeded in plats of one fifty-fifth of an acre each, and these were replicated five times, making five plats of each variety. The cultural experiments were continued on the 1914 basis In 1916 all plats were one fifty-fifth of an acre in size. The varieties were replicated five times and the cultural experiments thrice. In 1915 and 1916 numerous varieties were grown in single fifty-fifth acre plats to increase the seed stocks.

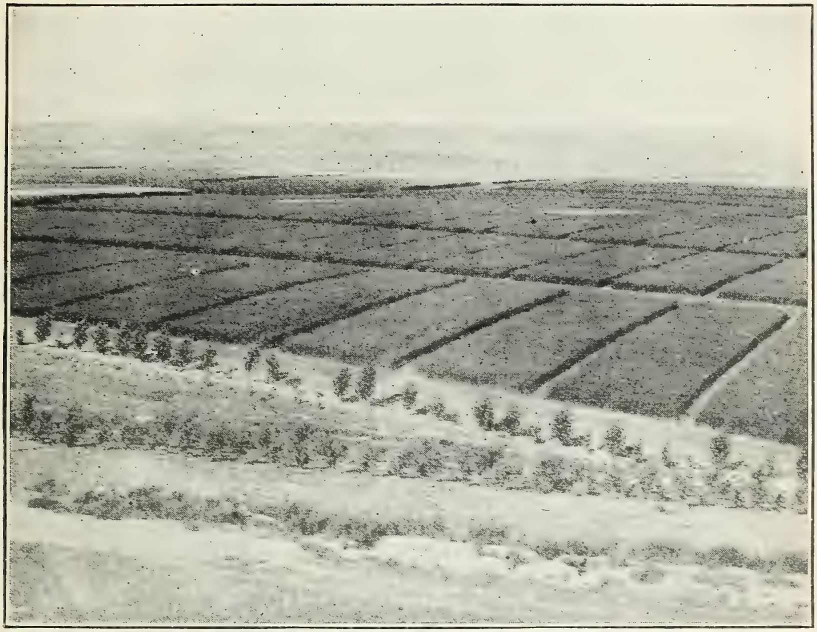

FIG. 1.—Panoramic view of plat experiments with flax at Mandan, N. Dak., in 1914. The experiments in 1915 and 1916 were on fields in the left and right background, respectively, under similar conditions.

All plats are 8 rods long. The fifty-fifth-acre plats are one drill width wide, or 5.5 feet from outside row to outside row. The alleys in 1914 and 1915 were 30 inches wide. In 1916 these were reduced to 18 inches, in order to overcome some of the border effect previously noted. Grain does not lodge as badly along the borders of plats when the narrower alleys are used, and less chance of admixture in harvesting results. Between the replications, however, an additional foot of space in the alleys was left to permit room for the binder bull wheel at harvest.

The varieties were seeded in the same order in each replication. In 1916 all the varietal plats were in one continuous series, but in 1914 and 1915 it was necessary to utilize parts of two or more of the series into which the station farm is divided. To obtain as representative conditions as possible the varieties were sown in reverse order when it was necessary to carry a replication over from one series to the adjoining one. For example, two of the replications and part of a third might be sown on one series, the varieties appearing in the same order in each replication, running from north to south. The remainder of the third and all of the fourth and fifth replications would then be sown on the adjoining series, beginning at the south end and running from south to north. In this arrangement, plats of the same variety approach each other at one point, as shown in the arrangement of the numbers below:

1	2	3	4	5	6	7	8	9	10	11	12	13	14	1	2	3	4	5	6	7
14	13	12	11	10	9	8	7	6	5	4	3	2	1	14	13	12	11	10	9	8

Different experiments have required nursery rows of various lengths. In 1914 and 1915 the agronomic nursery was seeded with the ordinary grain drill in single rows 8 rods long, spaced 1 foot apart. This was found to be unsatisfactory, and in 1916 the nursery was seeded with a hand garden drill in rows 34 feet 4 inches long, spaced 1 foot apart, and replicated thrice. This permitted a better distribution of each variety over the plat and a determination of the probable error of the experiment. More uniform seeding was obtained, and the harvesting and thrashing operations were facilitated. The number of varieties can always be determined and the series arranged so that all replications are evenly distributed.

In 1914 head selections were grown in 5-foot rows, but in 1915 and 1916 these and new introductions were grown in rows 17 feet 2 inches long. The yield in bushels per acre from a row of this length may be calculated readily by weighing the thrashed seed in grams and dividing by 10. The rows in the replicated nursery are twice this length, so that yields in bushels per acre may be figured by dividing the yield in grams per row by 5 or multiplying it by 0.2.

Rows in the breeding nursery where hybrids are studied have either been 5 feet in length or have varied with the quantity of seed available.

PREPARATION OF THE LAND.

The experiments here reported were all conducted on the same general field, being a part of the table-land formed by the postglacial terrace already discussed. Part of this land was broken in the summer of each of the successive years 1913, 1914, and 1915. This permitted backsetting the same fall. Each year the flax was grown on land which had been broken and backset the previous summer, and double-disked and harrowed in the spring before seeding. A disk drill was used in seeding the plats. Alleys and roads were cultivated at intervals during the season, and hand weeding the plats was necessary in order to maintain uniform conditions for all plats and to keep the station free from undesirable weeds. Yields from experimental areas probably should be discounted somewhat, to offset the favorable conditions arising from the effect of the alleys upon the plats and the hand pulling of weeds, which doubtless would have lowered yields.

INTERPRETATION OF EXPERIMENTAL RESULTS.

Yield of seed is the predominating factor in the value of a variety or cultural method when flax is grown for the seed alone. Other factors are worthy of serious consideration, however. Some of these are earliness of maturity, a definite period of bloom, height, erectness of straw, and yield and quality of oil. Distinctive characters of flower or seed are desirable, but in the experiments reported no factors of this kind enter into consideration.

The continued growing of certain types and varieties in the nursery can be justified only on the basis of classification studies and their utilization in hybridization. Some possess characters or characteristics of growth which, if combined properly with other types, may give strains of superior value. At Mandan, too, the breeding experiments for the entire flax project are concentrated, and strains are continued here even when they do not appear promising, if they are known to be of value in other areas.

The yields obtained in these three years undoubtedly are high, as the rainfall during this period was excessive when compared with the normal for this section. It is doubtful, also, whether the results during three years supply an adequate expression of what may be expected from rates and dates of seeding, as these results vary greatly from year to year, depending upon the weather. The relative yields of the different varieties conform more or less closely, however, to those obtained in similar experiments at other stations.

FLAX EXPERIMENTS IN PLATS.

Plat experiments were confined to the study of varieties and of rates and dates of seeding. Complete experimental data were obtained on 14 varieties grown for the three years in replicated plats.

HISTORY AND DESCRIPTION OF VARIETIES.

The 14 strains and varieties in this experiment were selected from the most promising ones being grown at State and Federal stations in the Northwest in 1913. These had been or were assigned Cereal Investigations accession numbers and, for the sake of brevity, will be referred to by these numbers.

Table III shows the accession numbers used at Mandan, with the names of the varieties, the source of the seed, and the original source of the variety.

TABLE III.—*Accession numbers, names, and sources of seed of flax varieties grown in the plat experiments at Mandan, N. Dak.*

C. I. No.	Name.	Source of seed used at Mandan, seed grown in 1913 by—	Original source.
1	Select Russian (N. Dak. No. 608).	Experiment station, Moccasin, Mont.	N. Dak. experiment station.
2	Select Riga (N. Dak. No. 1214)	do	Do.
3	Damont (N. Dak. No. 1215)	do	Do.
4	Kazan (N. Dak. No. 1329)	do	Russia, 1903.
5	Stepan (N. Dak. No. 1340)	do	Do.
8	N. Dak. Resistant No. 52	C. H. Plath, Davenport, N. Dak.	N. Dak. experiment station.
12	Primost (Minn. No. 25)	Experiment station, Moccasin, Mont.	Minn. experiment station.
13	N. Dak. Resistant No. 114	H. L. Bolley, N. Dak. experiment station.	
14	N. Dak. Resistant No. 73	C. A. Williams, Fairmount, N. Dak.	
15	Idaho Common	F. W. Boehme, Geneva, Idaho	
16	N. Dak. No. 1221	Experiment station, Moccasin, Mont.	N. Dak. experiment station.
17	Frontier (N. Dak. No. 155)	do	Do.
18	Fargo Common (N. Dak. No. 1133)	do	Do.
19	Reserve	do	Edgeley substation, Edgeley, N. Dak.

Cereal Investigations Nos. 1, 2, 3, 4, 5, 16, 17, 18, and 19 were obtained in the spring of 1914 from the Judith Basin substation, Moccasin, Mont., where they had been used in experiments since 1911. In that year C. I. Nos. 1, 2, 3, 4, 5, and 16 were obtained directly from the North Dakota Agricultural Experiment station at Fargo. C. I. Nos. 17 and 18 were secured from the substation at Williston, N. Dak., where they were grown that year for the first time from Fargo seed. Seed sent to Moccasin from Williston evidently was grown at Fargo. C. I. No. 19 was obtained from the State substation at Edgeley, N. Dak., in 1917, under the name Russian; although it possibly is Frontier (C. I. No. 17, N. Dak. No. 155) or a selection from this variety, the State records are not clear on this point. The variety usually has given better results than Frontier in our experiments, and for this reason its identity has been maintained. It has been grown, distributed, and the results published under the name of Russian (C. I. No. 19).[1] Russian is a general term used to designate most of the blue-flowered brown-seeded flaxes grown in the Northwest. For this reason this variety is here renamed Reserve.

All of the varieties obtained by the Judith Basin substation from Fargo were selections and varieties developed by the agronomy department of the North Dakota Agricultural Experiment Station. Frontier (C. I. No. 17) is a variety which that station had distributed under the name Russian (N. Dak. No. 155), more recently named Frontier. C. I. Nos. 1 and 3 are selections from this variety. C. I. Nos. 2, 16, and 18 have originated from locally grown varieties and C. I. Nos. 4 and 5 were direct importations by the United States Department of Agriculture from Russia in 1903 as Seed and Plant Introduction Nos. 9906 and 9937, respectively.

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[1] Donaldson, N. C. Cereal experiments at the Judith Basin substation, Moccasin, Mont. U. S. Dept. Agr. Bul. 398, p. 36. 1916.

Hume, A. N., Champlin, Manley, and Martin, John. Flax culture in South Dakota. S. Dak. Agr. Exp. Sta. Bul. 169, p. 469–471. 1916.

Aune, Beyer. The work of the Belle Fourche reclamation project experiment farm in 1916, West. Irrig. Agr. Cir. 14, p. 23–24, 1917; in 1917, West. Irrig. Agr. Cir. 24, p. 27, 1918; in 1918, Dept. Cir. 60, p. 15–16, 1919.

Of the three North Dakota resistant varieties, C. I. No. 13 was seed obtained direct from Prof. H. L. Bolley and produced on his most diseased plat in 1913. C. I. Nos. 8 and 14 were not available from this source, and were obtained from farmers whose seed was recommended by the botany department of the North Dakota Agricultural College.

C. I. No. 15 was a commercial variety, obtained during the winter of 1913 from a farmer in Idaho.

All of the 14 varieties are of the blue-flowered type grown in the Northwest. Most of them can be classified as true seed-flax types. C. I. Nos. 12 and 13, however, have a more slender stem and compact panicle, and have previously been referred to as short-fiber flaxes.[1] C. I. Nos. 4, 14, and 15 are more or less intermediate between the short-fiber and true seed-flax types, in certain seasons resembling one and in other seasons the other group. C. I. No. 15 was a mixture so lacking in uniformity that it was discarded from the experiments at the end of the third season.

AGRONOMIC RESULTS.

Table IV presents the annual and average yields of the flax varieties that were grown in plats, in the order of their highest average yield, together with the annual and average probable errors. The annual probable errors were computed from the formula

$$R = \pm \frac{0.8453}{n\sqrt{n-1}},$$

and the probable error of the average was obtained by the formula

$$R = \pm \frac{\sqrt{a^2 \pm b^2 + c^2}}{3},$$

when R equals the probable error of the average, and a, b, c the probable errors of the three results.

While slight variations in yield are noted between varieties from year to year, the relative position of the varieties was the same in both the 2-year and the 3-year averages. This order classifies them automatically, ranging from highest to lowest yielders, from the most pronounced seed types through the intermediate varieties to the slender-stemmed short-fiber types. For new breaking under semiarid conditions the seed-flax varieties of the so-called Russian type are best adapted. Resistant varieties should not be held at a premium under these conditions.

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[1] Clark, C. H. Seed-flax production, U. S. Dept. Agr., Farmers' Bul. 785, 20 p., illus. 1917.

TABLE IV.—*Annual and average yields of fourteen varieties and strains of flax grown on plats at the Northern Great Plains Field Station, Mandan, N. Dak., during 1914, 1915, and 1916.*

Variety.	C. I. No.	Yield per acre (bushels).			
		1914[1]	1915[2]	1916[2]	Average.
Reserve	19	17.6±1.9	19.3±1.2	14.0±0.8	17.0±1.4
Select Riga (N. Dak. No. 1214)	2	17.6±0.4	19.3±1.3	13.8±1.1	16.9±1.0
Damont (N. Dak. No. 1215)	3	19.0±1.4	17.6±1.5	13.9±0.8	16.8±1.0
Select Russian (N. Dak. No. 608)	1	15.6±0.5	20.3±1.8	14.1±0.8	16.7±1.2
Frontier (N. Dak. No. 155)	17	15.4±1.2	19.0±1.3	14.3±0.9	16.2±1.1
N. Dak. No. 1221	16	16.1±0.1	16.7±1.4	14.2±0.8	15.7±0.9
N. Dak. Resistant No. 52	8	15.0±0.3	17.1±1.7	13.3±0.9	15.1±1.1
Stepan (N. Dak. No. 1340)	5	14.7±1.3	16.9±1.1	13.4±0.7	15.0±1.1
Fargo Common (N. Dak. No. 1133)	18	13.9±0	14.9±1.2	12.7±0.7	13.8±0.8
Idaho Common	15	15.6±0.8	13.4±1.3	12.4±0.6	13.8±1.0
N. Dak. Resistant No. 73	14	14.3±0.3	13.9±1.0	12.7±0.6	13.6±0.7
Kazan (N. Dak. No. 1329)	4	12.3±1.4	13.5±0.9	12.9±1.0	12.9±1.1
N. Dak. Resistant No. 114	13	14.9±0.8	12.5±0.6	9.2±0.3	12.2±0.7
Primost	12	14.4±0.1	9.8±1.3	10.0±0.5	11.4±0.8
Average	......	15.5	16.0	12.9	14.8

Variety.	C. I. No.	Yield of oil (per cent).				Actual yield of oil per acre (pounds).			
		1914	1915	1916	Average.	1914	1915	1916	Average.
Reserve	19	35.64	35.50	37.25	36.13	351.3	383.7	292.0	342.3
Select Riga (N. Dak. No. 1214)	2	35.20	39.14	37.75	37.36	346.9	423.0	293.8	354.6
Damont (N. Dak. No. 1215)	3	34.00	33.80	39.00	35.60	361.8	333.1	303.6	332.8
Select Russian (N. Dak. No. 608)	1	33.00	34.42	39.75	35.72	288.3	391.3	313.9	331.2
Frontier (N. Dak. No. 155)	17	34.40	37.64	37.00	36.35	296.7	400.5	296.3	331.2
N. Dak. No. 1221	16	35.80	41.38	36.25	37.81	322.8	387.0	288.3	332.7
N. Dak. Resistant No. 52	8	36.00	35.67	34.40	35.36	302.4	341.6	256.2	300.1
Stepan (N. Dak. No. 1340)	5	34.00	36.40	38.50	36.30	279.9	344.5	288.9	304.4
Fargo Common (N. Dak. No. 1133)	18	35.10	35.72	38.75	36.52	273.2	298.0	275.6	282.3
Idaho Common	15	33.90	35.94	37.20	35.68	296.2	269.7	258.3	274.7
N. Dak. Resistant No. 73	14	32.80	36.40	33.40	34.20	262.7	283.3	237.5	261.2
Kazan (N. Dak. No. 1329)	4	33.60	40.16	38.50	37.42	231.4	303.6	278.1	271.0
N. Dak. Resistant No. 114	13	33.24	34.72	34.50	34.15	277.4	243.0	177.7	232.7
Primost	12	31.44	35.70	34.35	33.83	253.5	195.9	192.4	213.9

[1] Average yields from duplicated twentieth-acre plats.
[2] Average yields from fifty-fifth-acre plats replicated 5 times.

If we compute the probable errors of the differences in these average results and multiply them by 3, as is customarily done, we find that, of the fourteen varieties, C. I. Nos. 13 and 12 are the only two in the experiment which are significantly poorer in yield than C. I. No. 19, the highest yielding strain. Both of these, however, are significantly lower in yield than the six most productive varieties.

Reserve (C. I. No. 19) proved its superiority under these conditions, as it has in numerous other experiments at other stations. Select Riga (C. I. No. 21), which has never been distributed commercially, gave practically the same results in the three years. With the exception of C. I. No. 2, the first four varieties are strains or selections of Frontier (C. I. No. 17), which is fifth in order of yield. Damont (C. I. No. 3), which is third on the list and not significantly poorer than the other two, is most uniform, has a more determinate blooming period, and has proved superior at stations in hotter or more arid sections. Under irrigation its growth habits are preferable to those of some of the other varieties. Seed of this variety has been distributed from several of the experiment stations.

C. I. No. 8, one of the North Dakota resistant varieties, was seventh in order of yield. This variety approaches the true seed-flax type more nearly than any of the other resistant strains. It is widely distributed in North Dakota and particularly in Montana, where in several of the northeastern counties it is the principal flax variety grown. While it is not a significantly poorer yielder than the best strain on the basis of statistical comparison, neither is it significantly a higher yielding strain than C. I. Nos. 13 or 12, and in each of the three years, and in the average of all, it produced about 2 bushels per acre less than the three highest yielders. It is a good, uniform variety, with considerable careful breeding behind it, and its distribution for growing on new land should be encouraged where better varieties are not available. Its name, however, has come to be a misnomer, for in the last few years, from one cause or another, it has ceased to retain the qualities of wilt resistance which it once possessed, and it can no longer be recommended as a resistant flax for those sections where flax is seeded on old land and where resistant flax should be grown.

North Dakota Resistant No. 114 (C. I. No. 13) is the only variety which can be safely recommended for old land, and one must be sure he is obtaining the true variety. It should be remembered that the behavior of this flax on new lands and under semiarid conditions is no proof of what the variety will do where it is particularly adapted. It is the one variety to be recommended at present for the eastern Dakotas, Minnesota, and Wisconsin where flax is grown on old land. North Dakota Resistant No. 73 (C. I. No. 14) is a better-yielding variety than North Dakota Resistant No. 114 (C. I. No. 13), but it is less widely distributed and not as wilt resistant as the latter.

In Table IV data are also presented on the percentage yields of oil and also the actual yield of oil in pounds per acre. This shows that the productive seed-flax strains also produce higher percentages of oil, and hence considerably greater oil yields, than the intermediate and short-fiber strains.

Table V shows the annual and average agronomic data recorded for the fourteen varieties of flax in the 3-year period from 1914 to 1916, inclusive.

TABLE V.—*Agronomic data of fourteen varieties and strains of flax grown on plats at the Northern Great Plains Field Station, Mandan, N. Dak., during 1914, 1915, and 1916.*[1]

Variety.	C. I. No.	Date headed.				Date ripe.				Emergence to maturity (days).			
		1914	1915	1916	Average.	1914	1915	1916	Average.	1914	1915	1916	Average.
		July	Aug.	July	July	Aug.	Sept.	Aug.	Aug.				
Reserve	19	18	16	24	30	15	7	16	23	88	104	93	95
Select Riga (N. Dak. No. 1214)	2	18	16	21	29	11	6	13	21	84	103	90	92
Damont (N. Dak. No. 1215)	3	18	16	21	29	14	6	13	23	88	103	90	94
Select Russian (N. Dak. No. 608)	1	18	16	21	29	14	6	13	23	88	103	90	94
Frontier (N. Dak. No. 155)	17	18	16	23	30	15	7	15	23	88	104	92	95
N. Dak. No. 1221	16	19	16	22	30	13	7	15	22	86	104	92	94
N. Dak. Resistant No. 52	8	16	16	25	30	13	7	16	23	86	103	93	94
Stepan (N. Dak. No. 1340)	5	18	16	23	30	12	7	14	22	86	104	91	94
Fargo Common (N. Dak. No. 1133)	18	18	16	25	30	13	7	15	22	86	104	92	94
Idaho Common	15	17	16	22	29	12	3	9	19	85	100	86	90
N. Dak. Resistant N o. 73	14	16	16	21	29	12	4	12	20	85	101	89	92
Kazan (N. Dak. No. 1329)	4	18	16	21	29	10	3	11	19	84	100	88	91
N. Dak. Resistant No. 114	13	15	16	20	28	8	1	9	17	81	98	86	88
Primost (Minn. No. 25)	12	18	16	21	29	8	(2)	9	16	81	98	86	88

Variety.	C. I. No.	Proportion of straw to grain.				Weight per bushel (pounds).				Weight of 1,000 seeds (grams).			
		1914	1915	1916	Average.	1914	1915	1916	Average.	1914	1915	1916	Average.
Reserve	19	2.4:1	1.8:1	2.0:1	2.1:1	54	54	55.2	54.4	4.515	5.082	4.555	4.717
Select Riga (N. Dak. No. 1214)	2	2.4:1	2.2:1	2.3:1	2.3:1	54	55	55.2	54.7	4.477	5.183	4.696	4.785
Damont (N. Dak. No. 1215)	3	2.1:1	2.7:1	2.3:1	2.4:1	54.3	54	55.2	54.5	4.500	5.208	4.541	4.750
Select Russian (N. Dak. No. 608)	1	2.5:1	2.4:1	2.4:1	2.4:1	53.8	54	55.2	54.3	4.510	5.165	4.666	4.780
Frontier (N. Dak. No. 155)	17	2.6:1	2.4:1	2.3:1	2.4:1	54.8	55	55.5	55.1	4.399	5.238	4.627	4.755
N. Dak. No. 1221	16	2.3:1	3.6:1	2.3:1	2.7:1	54.3	54	55.5	54.6	4.284	5.152	4.587	4.674
N. Dak. Resistant No. 52	8	2.3:1	2.2:1	2.3:1	2.3:1	55	54	54.6	54.5	4.636	5.240	4.659	4.845
Stepan (N. Dak. No. 1340)	5	2.5:1	2.4:1	2.4:1	2.4:1	53.8	55	56	54.9	4.356	5.085	4.531	4.657
Fargo Common (N. Dak. No. 1133)	18	2.7:1	2.7:1	2.6:1	2.7:1	54.3	54	55.6	54.6	4.554	5.177	4.702	4.811
Idaho Common	15	1.9:1	2.4:1	2.3:1	2.2:1	54.3	55	56.2	55.2	3.951	4.678	4.020	4.216
N. Dak Resistant No. 73	14	2.3:1	3.1:1	1.9:1	2.4:1	55	54	56.9	55.3	3.849	4.685	4.143	4.226
Kazan (N. Dak. No. 1329)	4	2.3:1	2.6:1	2.3:1	2.4:1	53.5	55	55.5	54.7	4.397	4.969	4.539	4.635
N. Dak. Resistant No. 114	13	2.3:1	2.8:1	2.4:1	2.5:1	55.3	55	55.8	55.4	3.851	4.346	3.832	4.010
Primost (Minn. No. 25)	12	2.4:1	1.9:1	2.9:1	2.4:1	54.8	55	55.9	55.2	3.810	4.612	3.960	4.127

[1] Dates of emergence: In 1914, all varieties May 19; in 1915 C. I. Nos. 8, 13, and 14 on May 27 and all others on May 26; in 1916, all varieties, May 15; 3-year average, all varieties May 20. The average height of the plants varied from 28 to 31 inches in 1914, C. I. Nos. 1, 4, 14, 17, and 19 averaging 28 inches; C. I. No. 12, 30 inches; C. I. No. 16, 31 inches; and all others, 29 inches. In 1915 the average height varied from 24 to 26 inches, all averaging 24 inches except C. I. Nos. 1, 3, 8, 16, 17, and 18, which averaged 25 inches, and C. I. No. 2, which averaged 26 inches. In 1916 the average height varied from 20 to 22 inches, C. I. No. 13 averaging 20 inches, C. I. Nos. 2, 4, 5, 12, and 15, 21 inches; and all others, 22 inches. The 3-year average height for all varieties ranged from 24 to 26 inches. C. I. Nos. 4 and 13 averaged 24 inches in height; C. I. No. 16, 26 inches; and all others, 25 inches.

[2] August 31.

Slight differences between varieties in the dates of emergence and of first bloom are shown in Table V. The intermediate and short-fiber strains bloom a day or so in advance of the other strains, but their earliness becomes more pronounced during the ripening period. C. I. Nos. 13 and 12 usually are a week earlier in maturing, while the intermediate types are distinctly earlier than the true seed-flax varieties. This difference is shown most clearly in the column headed "Emergence to maturity."

While 90 days usually is regarded as the normal period required for flax development, the effect of a cool, cloudy season is shown in the results obtained in 1915. Similar results follow when flax is sown late and the growing period extends into a cool, wet fall. Then danger of frost is threatened also. As a result of the cool season in 1915 the 3-year average growing period is longer than ordinarily would be expected.

Little difference in height of straw is noted. The averages for C. I. Nos. 4 and 13 are slightly lower than for the other strains, and this can be regarded as a fair expression of a slight tendency to shorter growth in these two strains. Both have slender stems and compact panicles, and this type of plant usually is not as tall as the coarser-stemmed seed-flax types. C. I. No. 12 is of the same type, but in this strain there is a considerable portion of fiber-flax admixture, which is reflected in the heights recorded.

Ordinarily the slender varieties possess a higher proportion of straw to grain, as shown in Table V. One might expect the reverse, but the restricted development of their panicles causes a limited seed production per plant. In humid areas, where the straw is of greater value, this loss in yield may be overcome to some extent by heavier seeding and closer spacing.

Data on weight per bushel and weight of 1,000 seeds in the different years are also given in Table V. Here it is seen that the seeds of intermediate and short-fiber varieties weigh slightly more per bushel than those of the seed-flax strains, but that the weight of 1,000 seeds of these types is much less than for the seed-flax samples. Comparing these results with those of the oil percentages in Table IV, it is apparent that there is a positive correlation between size of seed and oil percentages in these varieties and that the seed-flax strains are superior to the short-fiber strains in both of these characters.

ANALYTICAL RESULTS.

The true value of a flax variety can not be determined solely by its productiveness or resistance to disease. Flax is an oil-producing plant, and the relative values of different varieties must be based not only on agronomic characters but on physical and chemical determinations of the quantity, quality, and character of the oils produced by each. Such studies have been made in connection with a comprehensive series of tests of all the varieties in the plat experiments herein discussed, and the data obtained are shown in Table VI.

Rabak,[1] in his first paper dealing with one phase of these studies, gives a brief discussion of the properties studied and the methods employed. The following is a quotation from his paper:

> The present investigation was undertaken in order to compare the oils from the various flax samples. . . . The comparison in question should determine tentatively those varieties producing seeds with the highest yield of oil as well as oil of

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[1] Rabak, Frank. Influence on linseed oil of the geographical source and variety of flax. U. S. Dept. Agr. Bul. 655, 16 p. 1918.

the best quality. Information of such character is of the utmost importance in connection with the production and improvement of this staple crop. However, it is not only important to ascertain the high oil-yielding varieties of seeds but the properties and general behavior of the oils are of equal importance. The physical and chemical properties of the oils determine their value to a large extent. In order to facilitate the best comparison, only those properties which admit of accurate measurement and which have a direct bearing upon the quality of the oils were considered.

Color, specific gravity, and index of refraction are important physical properties in which variations can easily be detected. . . . The specific gravity and the refractive index, which have much significance as regards the general composition of the oils, were readily determined.

The chemical properties are perhaps most important from the standpoint of the composition of the oils. The acid, saponification, and iodin values are the most important chemical constants. The acid value of the linseed oils is affected by a number of conditions. Factors such as rain or moisture during harvest and the storing of the moist flax after harvest, which would tend to produce molding of the seed, will modify considerably the acid value of the oil. The saponification value representing the sum of the acid and ester values is a combined measure of the free acids and glyceryl esters contained in the oil.

Linseed oil consists for the most part of glyceryl esters of linoleic and linolic acids. These unsaturated fatty acids possess the property of absorbing iodin. This property is known as the iodin value and is perhaps the most important of the chemical constants. The iodin value is a direct criterion of the proportion of these fatty acids present in the oil, and since these acids determine the drying property of linseed oil the iodin value becomes an index of this property.

The usefulness of linseed oil in the industries is based upon the property of the oil to dry to a tough elastic film when exposed in thin layers to the air. This oil is a typical example of a class of fatty oils known as drying oils. Oils of this character are composed largely of glycerids of unsaturated fatty acids which possess the property of absorbing oxygen when exposed to the air. The absorption of oxygen by linseed oil alters its composition and is accompanied by the formation of a compound known as linoxyn, which constitutes the tough elastic skin so familiar when the oil is allowed to dry. The usefulness of linseed oil as a protective coating is due entirely to the formation of the compound linoxyn, which is resistant to the effects of heat and moisture of the outside elements to a remarkable degree.

Coincident with the absorption of oxygen there occurs an increase in the weight of the oil, and the more rapid the increase in weight the greater is the rapidity of drying, and vice versa. Advantage was taken of this property in order to determine the relative drying value of the various oils under consideration.

Two methods were used for the extraction of the flax samples, namely, ether extraction and cold expression. The former method was applied to determine the actual yield of oil in the seeds, while the method of cold expression was employed to obtain working samples of the various oils for the determination of the physical and chemical constants. Ether extractions were made by means of the customary Soxhlet extractors, while a small laboratory hydraulic press served for the cold expression of the oil. The yields of oil given in all cases represent ether-extracted oils, whereas all physical and chemical properties were determined upon cold-pressed oils.

It must be borne in mind that these cold-pressed samples differ from ordinary commercial raw linseed oils, being obtained under entirely different conditions. The results obtained are therefore comparable with each other, but not with commercial linseed oils.

The color was carefully noted in each case. Considerable diversity appeared, and the colors are described as well as possible in order to bring out the existing differences.

The specific gravity and the refractive index, being affected by the composition of the oils, were carefully determined. Both of these constants bear a certain relationship to the composition of the oil.

TABLE VI.—*Physical and chemical determinations of the oils of the fourteen varieties and strains of flax grown on plats at the Northern Great Plains Field Station, Mandan, N. Dak., during 1914, 1915, and 1916.*

Variety.	C. I. No.	Specific gravity at 24° C.				Index of refraction at 24° C.				Acid value.			
		1914	1915	1916	Average.	1914	1915	1916	Average.	1914	1915	1916	Average.
Reserve	19	0.9274	0.9301	0.9282	0.9286	1.4783	1.4787	1.4777	1.4782	1.07	0.55	0.89	0.84
Select Riga (N. Dak. No. 1214)	2	.9284	.9290	.9284	.9286	1.4781	1.4788	1.4774	1.4781	1.22	.60	.67	.83
Damont (N. Dak. No. 1215)	3	.9280	.9298	.9280	.9286	1.4781	1.4790	1.4775	1.4782	1.11	.86	.63	.87
Select Russian (N. Dak. No. 608)	1	.9278	.9291	.9304	.9291	1.4785	1.4790	1.4779	1.4785	1.11	.78	.70	.86
Frontier (N. Dak. No. 155)	17	.9278	.9300	.9272	.9283	1.4785	1.4787	1.4767	1.4780	1.05	.88	.80	.91
N. Dak. No. 1221	16	.9289	.9294	.9304	.9296	1.4792	1.4785	1.4775	1.4784	1.09	.89	.85	.94
N. Dak. Resistant No. 52	8	.9276	.9291	.9300	.9289	1.4789	1.4785	1.4779	1.4784	1.08	.76	1.04	.96
Stepan (N. Dak. No. 1340)	5	.9272	.9299	.9305	.9292	1.4791	1.4791	1.4775	1.4786	.91	.83	1.11	.95
Fargo Common (N. Dak. No. 1133)	18	.9285	.9300	.9275	.9287	1.4787	1.4783	1.4769	1.4780	1.06	.76	.98	.93
Idaho Common	15	.9280	.9294	.9279	.9284	1.4787	1.4789	1.4777	1.4784	.98	.56	.94	.83
N. Dak. Resistant No. 73	14	.9285	.9296	.9269	.9283	1.4787	1.4788	1.4768	1.4781	1.14	.62	.81	.86
Kazan (N. Dak. No. 1329)	4	.9276	.9293	.9274	.9281	1.4790	1.4787	.4772	1.4783	1.00	.98	.64	.87
N. Dak. Resistant No. 114	13	.9285	.9300	.9345	.9310	1.4795	1.4790	1.4786	1.4790	1.04	.78	1.41	1.08
Primost (Minn. No. 25)	12	.9278	.9292	.9279	.9283	1.4790	1.4788	1.4770	1.4783	1.01	.95	.72	.89

Variety.	C. I. No.	Saponification value.				Iodin value.				Time required to dry (days).			
		1914	1915	1916	Average.	1914	1915	1916	Average.	1914	1915	1916	Average.
Reserve	19	192.1	188.0	192.0	190.7	159.3	159.3	166.0	161.7	10	19	22	17
Select Riga (N. Dak. No. 1214)	2	192.0	191.9	192.0	192.0	165.3	162.7	172.1	166.7	9	18	10	12
Damont (N. Dak. No. 1215)	3	192.5	199.8	189.7	194.0	164.3	160.7	170.5	165.2	10	20	10	13
Select Russian (N. Dak. No. 608)	1	190.8	194.6	192.5	192.6	162.5	161.2	168.5	164.1	6	10	13	13
Frontier (N. Dak. No. 155)	17	192.4	189.5	193.0	191.6	161.4	166.6	164.6	164.2	12	18	23	18
N. Dak. No. 1221	16	193.2	188.9	193.4	191.8	156.0	163.6	167.2	162.3	8	16	12	12
N. Dak. Resistant No. 52	8	190.9	188.3	193.8	191.0	162.5	162.0	172.1	165.5	10	18	10	13
Stepan (N. Dak. No. 1340)	5	193.0	186.8	194.9	191.6	164.3	160.5	166.0	163.6	12	16	10	13
Fargo Common (N. Dak. No. 1133)	18	191.9	187.7	194.4	191.3	162.0	161.4	165.4	162.9	10	21	14	15
Idaho Common	15	190.8	186.7	190.8	189.4	160.4	161.6	167.5	163.2	8	18	15	14
N. Dak. Resistant No. 73	14	193.1	186.6	191.7	190.5	164.0	162.7	166.3	164.3	14	18	17	16
Kazan (N. Dak. No. 1329)	4	190.4	187.9	192.4	190.2	159.0	159.9	171.9	163.6	10	19	10	13
N. Dak. Resistant No. 114	13	190.2	187.0	192.7	190.0	162.4	163.3	164.4	163.4	10	18	7	12
Primost (Minn. No. 25)	12	191.9	186.9	188.6	189.1	161.7	162.4	170.4	164.8	10	16	10	12

PHYSICAL PROPERTIES OF THE OIL.

The data on the specific gravity of the various samples grown at Mandan presented in Table VI show that while there is a slight variation between varieties in the same year, these variations are not consistent from year to year. Greater variation appears to occur between all varieties in different years. Although ordinarily it is assumed that high specific gravity is correlated with a high index of refraction, high iodin value, and rapid drying qualities, based on a comparison of different types of oils, no such correlation is found in the results of this study. The specific gravity was high in most of the 1915 samples, but this was not reflected in the chemical characters noted or in the drying properties of these oils that year. All three of the other characters were, in fact, lower in 1915.

The figures for the index of refraction are quite similar in 1914 and 1915 and lower in 1916. These, in turn, are negatively rather than positively correlated with the chemical and drying properties of the oil.

CHEMICAL PROPERTIES OF THE OIL.

The acid values of the oils in 1915, as shown in Table VI, were abnormally low, indicating that hydrolysis or oxidation and a consequent liberation of free fatty acids had taken place. This conforms with the facts, for at the time of harvest cool, cloudy weather continued for more than a month. The varieties ripened slowly. The straw remained green. Even after the flax had been in the shock for more than the ordinary length of time, thrashing was discontinued because of the failure of the seed to dry out sufficiently to make storing safe.

It is interesting to note in this connection that the high-producing true seed-flax types were at a disadvantage in this respect in 1915. All of the late-maturing varieties had materially lower acid values in that year than the earlier types. C. I. No. 3, which has a more definite blooming period than the others, was not so adversely affected. This, however, apparently had little effect upon the yield of either the seed or the oil.

The saponification values of the oils in 1915 show a more or less positive correlation with the acid values in that year, as was to be expected. Here again C. I. No. 3 appears to advantage.

More definite and consistent differences between varieties are apparent in the iodin values given in Table VI. These, in turn, are more significantly correlated with drying properties. Even here, there are several cases in which numerous individual samples showed a low iodin value, but dried in a remarkably short period. C. I. Nos. 19, 16, 15, and 4 in 1914 and C. I. No. 5 in 1916 are clear examples. Taking the three-year average, however, it is evident that Reserve (C. I. No. 19) produces an oil with lower iodin value and slower drying properties than C. I. No. 2 or No. 3, which in point of seed production are equally good. North Dakota Resistant No. 52, another promising seed-flax type, also produces a rapid-drying oil. C. I. No. 2 is the only seed-flax variety which in the 3-year average dries in as short a period as the short-fiber varieties, C. I. Nos. 13 and 12. C. I. Nos. 3 and 8, however, give higher iodin values than these short-fiber types in this average.

RATE-OF-SEEDING EXPERIMENTS.

When seed flax sells at $4 or more per bushel, the importance of the economical use of seed is apparent. Table VII shows the annual and 3-year average yields of flax when different rates of seeding were used. In these experiments, seedings at the rate of 20 pounds to the acre produced the best average yields in the three years. When the probable errors of these results are considered, practically no significant differences are indicated except in one or two of the yearly averages. While 10 pounds to the acre is probably too light a seeding, little advantage seems to be gained by seeding at a heavier rate than 20 pounds under semiarid conditions. Of course, if the seed bed is poorly prepared, more seed will be necessary to insure adequate seeding.

Table VII.—*Annual and average yields obtained in the rate-of-seeding experiments with Reserve (C. I. No. 19) flax at Mandan, N. Dak., for the years 1914, 1915, and 1916.*

Rate of seeding.	Yield per acre (bushels).			
	1914	1915	1916	Average.
10 pounds per acre	14.6±0.8	22.5±0.8	14.7±0.8	17.3±0.8
15 pounds per acre	15.1±3.0	24.0±1.3	14.6±0.5	17.9±1.9
20 pounds per acre	14.3±2.4	25.4±0	16.0±0.2	18.6±1.4
25 pounds per acre	14.1±0.8	24.1±0.5	15.9±0.8	18.0±0.7
30 pounds per acre			16.7±0.3	

DATE-OF-SEEDING EXPERIMENTS.

The marked similarity in the three seasons here reported discredits to a large extent a date-of-seeding experiment continued for so short a period. Results so far obtained, as given in Table VIII, indicate an advantage for early seeding on new breaking in this area.

Table VIII.—*Annual and average yields obtained in the date-of-seeding experiments with Damont (C. I. No. 3) flax at Mandan, N. Dak., for the years 1914, 1915, and 1916.*

Date of seeding.	Yield per acre (bushels).			
	1914	1915	1916	Average.
April 15 to 17		16.6	15.2±0.2	15.9
May 1 to 7	17.6±0.2	22.0±0.2	17.6±1.1	19.1±0.7
May 15 to 18	18.3±0.1	18.8±0.7	19.1±0.6	18.7±.05
June 1	12.3±0.2	19.1±0.5	17.1±0.5	16.2±0.7
June 15			10.1±0.3	

Seedings made as early as April 15 possibly are subjected more or less to late frosts, which reduce stands. Seeding should not be delayed after May 1, however, where the land is in condition. Figure 2 shows the relative appearance of Damont flax on July 17, 1914, seeded on May 15 and June 1, respectively. The May 15 seeding yielded that year 6 bushels more per acre than the June 1 seeding. Fair results, however, may be expected from early June seeding; in fact, June seedings often yield more than those made during the last two weeks in May. The yield is largely dependent upon the occurrence or absence in August of hot, drying winds, which usually have a tendency to cause the premature ripening of flax sown late in May. Evidence of this was seen in 1915, when a hot, dry spell was followed by a late, cool fall. The practice of seeding flax after June 10 to 15 is a questionable one. A marked decrease in yield can be expected, risks of damage by early fall frosts will be taken, and flax diseases are known to develop most severely in hot soils.

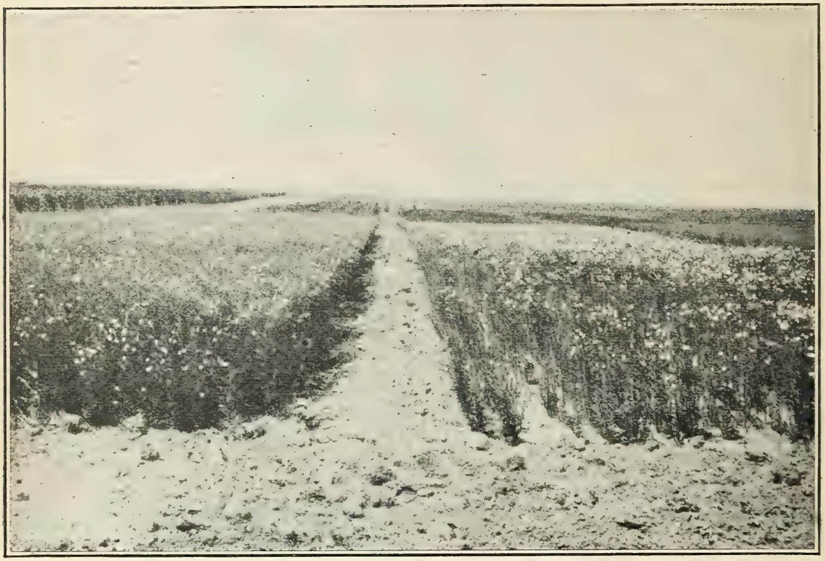

FIG. 2.—View showing plats in date-of-seeding experiment with Damont (C. I. No. 3) flax at the Northern Great Plains Field Station, Mandan, N. Dak. The plat at the left was sown on May 15 and that at the right on June 1. Photographed July 17.

FLAX EXPERIMENTS IN NURSERY ROWS.

SOURCE AND VARIABILITY OF MATERIAL.

In the plat experiments only those varieties were grown which had previously shown their adaptability to northwestern conditions. These, it has been explained, all conform more or less closely to one type. All are erect, sparsely branched tall varieties with blue flowers and a relatively small brown seed. Importations obtained through the Office of Foreign Seed and Plant Introduction during the winter of 1913-14 from widely separated countries showed an interesting range of types and characteristics. Many, while not adapted to northwestern conditions, have valuable characters. If these are utilized in breeding experiments, strains may be produced which are better adapted for the various regions where flax is grown in this country.

The question often arises whether Indian, Argentine, or Manchurian seed would be of value for seeding purposes in the United States. In order to throw some light on this subject, a representative assortment of varieties from India, Argentina, Manchuria, and other countries has been selected from the nursery experiments, and such data regarding them as are available are presented in Table XI in comparison with similar data obtained on numerous northern-grown varieties and selections. In some instances only one variety of a type was available.

TABLE IX.—*Tentative group classification of varieties of flax grown in the nursery-row experiments at Mandan, N. Dak., during 1914, 1915, and 1916.*

Group.	Designation.
No. 1	Textile fiber.
No. 2	Short fiber.
	(*a*) White flowers, brown seed.
	(*b*) Blue flowers, brown seed.
No. 3	European seed.
	(*a*) Slender stems, compact panicle.
	(*b*) Coarse stems, ramified panicle.
No. 4	Argentine.
	(*a*) Tall.
	(*b*) Short.
No. 5	Turkish.
No. 6	Golden. White flowers, golden seed.
No. 7	Chinese Turkestan.
No. 8	Abyssinian.
	(*a*) Blue flowers, white seed.
	(*b*) Blue flowers, brown seed.
No. 9	Indian.
	(*a*) White flowers, white seed.
	(*b*) Blue flowers, brown seed.
No. 10	Egyptian.

TABLE X.—*List of flax varieties grown in nursery-row experiments at Mandan, N. Dak., showing the Cereal Investigations number and the descriptive key number of each.*

Descriptive key No.	C. I. No.	Name of variety.
Group 1	32	Pskov.
Group 2-a	24	Ottowa White Flowering.
Group 2-b	13	N. Dak. Resistant No. 114.
	12	Primost (Minn. No. 25).
Group 3-a	46	Minnesota No. 114.
	14	N. Dak. Resistant No. 73.
	8	N. Dak. Resistant No. 52.
	1	N. Dak. Resistant No. 608.
	5	Stepan (N. Dak. No. 1340).
	3	Damont (N. Dak. No. 1215).
	16	N. Dak. No. 1221.
	45	N. Dak. No. 609.
	4	Kazan (N. Dak. No. 1329).
	18	N. Dak. No. 1133.
	2	Select Riga (N. Dak. No. 1214)
	17	Frontier (N. Dak. No. 155).
	19	Russian.
Group 3-b	72	N. Dak. Centgener No. 720.
	67	N. Dak. Centgener No. 499.
	68	N. Dak. Centgener No. 509.
	66	N. Dak. Centgener No. 498.
	69	N. Dak. Centgener No. 641.
	70	N. Dak. Centgener No. 643.
	6	Montana Common.
	74	N. Dak. Centgener No. 759.
	27	Novo Rossisk.
Group 4-a	65	Argentina (N. Dak. No. 1115).
Group 4-b	26	Canadian La Plata.
	44	La Plata.
Group 5	7	Turkish.
	30	Smyrna.
	31	Crete.
Group 6	25	Williston Golden.
	23	Lethbridge Golden.
	9	Dakota Golden.
Group 7	43	Chinese.
Group 8-a	36	Soddo White.
Group 8-b	5	Mundjar.
	37	Boulga.
	38	Soddo Brown.
	39	Metcha.
Group 9-a	40	Hoshangabad.
Group 9-b	20	Punjab.
	21	Jalaum.
	28	Benares.
	41	Calcutta.
	42	Bombay.
Group 10	33	Egyptian.
	34	Matania.

DESCRIPTIVE KEY TO VARIETIES.

No serious attempt is made here at classification, but the varieties fall into rather natural groups when arranged according to geographical sources. That these types may be clearly visualized for the reader, they are arranged in Table IX in accordance with a descriptive key, so that one type blends as imperceptibly as possible into the next. The numbers appearing in this key are repeated in Table X, so that the reader may be able to associate any of the C. I. numbers in Table XI with the geographical source or group type. Such an arrangement has been attempted in the nursery plantings, but this naturally is changed from year to year as a more definite classification of the material is obtained. The data presented in the two parts of Table XI are arranged in the same order, and a fair knowledge of the behavior and possibilities of the different types can be obtained from a careful study of these results.

TABLE XI.—*Agronomic and yield data for flax varieties grown in the nursery-row experiments at Mandan, N. Dak., during 1914, 1915, and 1916.*

C. I. No.	Height (inches).				Proportion of straw to grain.				Weight of 1,000 seeds (grams).			
	1914	1915	1916	Average.	1914	1915	1916	Average.[1]	1914	1915	1916	Average.
32	35	38	27	33.3	3.4:1	5.4:1	6.3:1	5.0:1	3.713	4.273	....	3.993
24	24	26	20	23.3	3.3:1	2.1:1	4.5:1	3.3:1	3.814	4.518	4.085	4.139
13	26	27	20	24.3	2.9:1	2.1:1	4.0:1	3.0:1	3.851	4.254	3.722	3.942
12	26	28	22	25.3	3.2:1	2.3:1	3.3:1	2.9:1	3.810	4.650	4.140	4.200
46	24	32	......	28.0	2.5:1	....	....	....	4.149	....	4.273	4.211
14	24	30	22	25.3	2.6:1	2.0:1	2.9:1	2.5:1	3.849	4.918	4.565	4.444
8	24	28	22	24.7	2.8:1	2.4:1	3.4:1	2.9:1	4.636	4.579	4.254	4.496
1	24	28	22	24.7	2.5:1	2.2:1	3.1:1	2.6:1	4.510	5.155	4.652	4.772
5	24	31	23	26.0	2.6:1	1.7:1	2.7:1	2.3:1	4.356	5.079	4.587	4.674
3	24	27	21	24.0	2.6:1	1.8:1	2.9:1	2.4:1	4.500	5.294	4.533	4.776
16	24	......	22	23.0	2.7:1	2.4:1	3.0:1	2.7:1	4.284	4.852	4.716	4.617
45	25	27	22	24.7	3.6:1	1.8:1	4.4:1	3.3:1	4.535	5.237	4.487	4.753
4	24	30	22	25.3	2.8:1	1.9:1	3.1:1	2.6:1	4.397	5.153	4.722	4.757
18	21	......	23	22.0	2.8:1	2.3:1	3.0:1	2.7:1	4.554	4.896	4.757	4.736
2	26	30	23	26.3	3.0:1	1.9:1	3.3:1	2.7:1	4.477	5.003	4.764	4.748
17	24	27	24	25.0	3.1:1	1.7:1	3.2:1	2.7:1	4.399	5.257	4.728	4.795
19	23	29	21	24.3	3.5:1	1.8:1	3.6:1	3.0:1	4.515	5.135	4.541	4.730
72	22	30	22	24.7	2.8:1	2.0:1	3.1:1	2.6:1	....	4.933	4.462	4.698
67	20	31	22	24.3	2.2:1	2.5:1	3.0:1	2.6:1	....	5.035	4.844	4.940
68	21	31	25	25.7	2.8:1	2.4:1	3.5:1	2.9:1	....	5.108	4.881	4.995
66	21	31	23	25.0	3.1:1	2.0:1	3.1:1	2.7:1	....	5.018	6.591	5.805
69	21	30	23	24.7	2.9:1	2.1:1	3.3:1	2.8:1	....	5.117	4.823	4.970
70	21	30	22	24.3	2.6:1	1.8:1	3.0:1	2.5:1	....	4.889	4.949	4.919
6	23	......	24	23.5	3.0:1	....	3.1:1	†3.1:1	5.059	....	5.542	5.301
74	22	29	22	24.3	3.7:1	2.1:1	2.8:1	2.9:1	....	5.068	4.674	4.871
27	20	26	21	22.3	3.0:1	1.5:1	2.9:1	2.5:1	5.315	5.921	5.408	5.548
65	28	30	24	27.3	5.4:1	2.4:1	4.0:1	3.9:1	....	5.894	4.423	5.159
26	18	20	17	18.3	2.4:1	1.4:1	3.1:1	2.3:1	6.803	7.950	7.185	7.313
44	22	......	19	20.5	3.1:1	....	3.6:1	†3.3:1	....	....	6.704	....
7	20	30	20	23.3	17.0:1	2.2:1	3.9:1	7.7:1	4.410	5.507	5.000	4.972
30	16	20	18	18.0	1.9:1	5.9:1	16.5:1	8.1:1	6.384	5.516	5.679	5.860
31	22	22	20	21.3	4.0:1	3.6:1	4.9:1	4.2:1	8.238	9.350	8.800	8.796
25	18	24	20	20.7	4.5:1	2.0:1	5.5:1	4.0:1	5.253	6.720	5.335	5.769
23	18	22	19	19.7	3.9:1	1.6:1	3.3:1	2.9:1	5.593	7.316	6.026	6.312
9	18	22	18	19.3	4.8:1	1.8:1	4.0:1	3.5:1	4.753	6.757	5.795	5.772
43	21	29	23	24.3	3.9:1	2.6:1	4.9:1	3.8:1	4.283	4.796	....	4.540
36	16	15	13	14.7	1.8:1	2.9:1	....	2.4:1	4.080	4.507	....	4.294
35	13	17	14	14.7	2.7:1	2.3:1	....	2.5:1	3.586	3.678	....	3.632
37	13	17	14	14.7	2.1:1	2.5:1	....	2.3:1	3.577	3.879	....	3.728
38	13	16	14	14.3	1.9:1	2.0:1	....	2.0:1	3.506	3.733	....	3.620
39	14	16	14	14.7	2.3:1	1.9:1	....	2.1:1	3.485	3.623	....	3.554
40	9	......	18	13.5	4.0:1	....	....	....	....	....	....	....
20	16	......	15	15.5	2.3:1	2.3:1	....	2.3:1	4.749	4.958	....	4.854
21	8	13	17	12.7	3.0:1	....	....	....	6.756	....	....	....
28	13	15	14	14.0	2.6:1	....	....	....	4.780	....	....	....
41	10	15	12	12.3	2.8:1	4.2:1	....	3.5:1	4.209	4.341	....	4.275
42	12	13	10	11.7	2.3:1	2.5:1	....	2.4:1	5.210	4.807	....	5.009
33	18	15	14	15.7	4.0:1	....	....	....	4.597	....	....	....
34	17	15	15	15.7	4.7:1	....	....	....	4.528	....	....	....

[1] Data unmarked are 3-year averages; those marked with a dagger (†) are 2-year averages.

TABLE XI.—*Agronomic and yield data for flax varieties grown in the nursery-row experiments at Mandan, N. Dak., during 1914, 1915, and 1916*—Continued.

[Data designated by an asterisk (*) relate to rows 17 feet 2 inches in length.]

C. I. No.	Yield per acre (bushels).				Yield of oil as determined by ether extraction (per cent).			
	1914	1915	1916	Average.	1914	1915	1916	Average.[1]
32	7.8	7.7	* 5.4	7.0	32.50	34.96	....	† 33.73
24	13.2	15.3	7.8	12.1	37.40	33.60	36.84	35.95
13	12.4	17.7	8.2	12.8	34.27	35.60	32.72	34.20
12	13.2	17.7	11.1	14.0	35.72	33.00	35.84	34.85
46	16.3	* 23.5	13.4	17.7	36.30	....	37.74	† 37.02
14	10.1	27.1	16.6	17.9	33.20	31.80	35.54	33.51
8	10.9	22.4	15.3	16.2	37.07	33.69	34.44	35.07
1	16.3	25.3	12.5	18.0	35.03	34.42	37.46	35.64
5	10.9	21.2	13.5	15.2	35.51	38.80	36.22	36.84
3	14.8	24.2	12.6	17.2	35.89	34.20	38.06	36.05
16	15.5	25.9	14.8	18.7	35.53	40.00	37.54	37.69
45	13.2	23.6	13.1	16.6	33.10	....	33.86	† 33.48
4	15.5	18.3	13.7	15.8	37.30	37.60	40.05	38.32
18	8.6	22.4	15.9	15.6	33.85	36.00	39.26	36.37
2	17.1	24.8	13.2	18.4	35.15	36.40	38.40	36.65
17	17.1	35.4	14.7	22.4	33.38	35.20	39.34	35.97
19	9.3	27.1	15.3	17.2	36.41	32.00	39.68	36.03
72	* 15.0	27.1	12.1	18.1	....	37.88	37.34	† 37.61
67	* 25.3	20.0	* 16.5	20.6	....	38.48	38.98	† 38.73
68	* 24.5	24.8	13.5	20.9	....	35.80	38.28	† 37.04
66	* 34.0	23.6	12.2	23.3	....	36.96	38.78	† 37.88
69	* 24.5	23.6	11.6	19.9	....	40.40	39.18	† 39.79
70	* 21.0	22.4	12.3	18.6	....	36.12	38.26	† 37.19
6	10.9	* 24.0	* 16.7	17.2	38.30	....	38.12	† 38.21
74	* 33.2	25.9	13.7	24.3	....	40.20	39.60	† 39.90
27	9.3	24.2	12.8	15.4	36.20	39.88	38.06	38.05
65	10.6	19.5	11.7	13.9	....	42.00	40.08	† 41.04
26	12.4	18.9	10.7	14.0	37.63	39.00	36.92	37.85
44	12.4	* 31.5	9.2	17.7	37.20	....	37.60	† 37.40
7	3.9	21.2	12.6	12.6	37.60	37.00	38.74	37.78
30	19.4	4.7	2.1	8.7	36.40	37.12	37.36	36.96
31	* 13.3	6.5	5.3	8.4	36.40	38.28	38.00	37.56
25	9.3	19.5	5.1	11.3	34.00	40.20	38.20	37.47
23	8.6	17.7	8.6	11.6	38.40	39.80	39.60	39.27
9	* 12.0	14.7	6.0	10.9	36.50	38.96	39.02	38.16
43	9.3	14.7	* 13.5	12.5	38.00	36.00	....	† 37.00
36	14.0	7.7	* 3.0	8.2	36.00	36.44	....	† 36.22
35	7.8	11.8	* 8.5	9.4	31.40	37.08	....	† 34.24
37	11.7	8.8	* 12.8	11.1	33.20	31.84	....	† 32.52
38	14.8	13.6	13.5	14.0	34.90	35.48	....	† 35.19
39	12.4	12.4	* 10.0	11.6	30.80	31.52	....	† 31.16
40	.8	....	* 6.6	2.5	....	....	....	....
20	14.0	10.6	* 4.7	9.8	36.30	35.44	....	† 35.87
21	0	*.5	* 3.0	1.2	32.00	....	....	....
28	5.5	* 4.0	*.5	3.3	37.40	....	....	....
41	4.7	1.8	* 1.7	2.7	32.10	....	....	....
42	5.5	3.5	* 1.5	3.5	36.50	....	....	....
33	2.3	* 3.5	1.0	2.3	31.70	30.08	....	† 30.89
34	2.3	* 4.5	1.3	2.7	32.50	30.60	....	† 31.55

[1] Data unmarked are 3-year averages; those marked with a dagger (†) are 2-year averages.

DISCUSSION OF VARIETIES BY GROUPS.

A short statement as to the varietal groups, noting their distinctive agronomic and chemical characteristics, will help to fix some of these types in mind.

1. *Textile fiber.*—Flax of the textile type is grown primarily for linen fiber. Limited acreages are produced in this country where linen industries are established, but no fiber flax is ordinarily grown on breaking for seed production. These varieties are from 6 to 12 inches taller than ordinary seed flaxes, have few or no basal branches, and produce a long, sparsely seeded panicle. The seeds are small and cinnamon colored. Both white and blue flowered types are common. C. I. No. 32 is a blue-flowered strain. Its relatively poor yield of seed and low oil content may be taken as fairly representative of this type when grown under northwestern conditions.

2. *Short fiber.*—The three outstanding varieties of the short-fiber type are C. I. Nos. 24, 13, and 12. C. I. No. 24 differs from the others in having a white blossom. Plants of the short-fiber type predominate in several other varieties; in fact, varieties in this group grade rather imperceptibly into varieties described in group 3 as having slender stems and compact panicles. A final classification of varieties will probably put all those described in groups 2, 3, 4, and 5 into one division but will subdivide them for height, erectness, and coarseness of stem. For the purposes of this paper it seemed desirable, however, to consider them separately. Short-fiber varieties tend to be slightly shorter than the true seed-flax types, have smaller seeds, are poorer yielders, and the seeds have a relatively lower oil content.

3. *European seed.*—This group comprises the types grown generally in the Northwest and includes most of the varieties already considered under the plat experiments. These are included in the nursery series to show their behavior in comparison with the other types and the relative results obtained in plat and nursery experiments. All are blue flowered and brown seeded and range in height from 22 to 28 inches. The average yields of seed and oil are superior to most of the other varieties grown in these experiments.

4. *Argentine.*—The tall Argentine strains are similar to the varieties in the European seed group which have coarse stems and ramified panicles. The short Argentine varieties range in height from 18 to 20 inches and ordinarily produce one or more basal branches. The yields of seed and oil compare favorably with the varieties in group 3, but the varieties included in Table IX are fairly well acclimated. New introductions are ordinarily shorter and usually lack uniformity, being commercial mixtures. One would be taking a big chance in using a commercial importation from Argentina for seeding in this country, and could not expect as profitable returns as from locally grown commercial seed.

5. *Turkish.*—Three varieties are included in the Turkish group, two of which were obtained from Smyrna and one from the Island of Crete. C. I. No. 7 was originally a copiously branched prostrate-growing type. Several years of culture in this country have resulted in natural selection toward an upright type, but the variety lacks uniformity, the proportion of straw to grain is always high, and the yield of seed is low. The seed is large and has a high oil content, but the variety can not be recommended. C. I. Nos. 30 and 31 are short, late, and do not yield satisfactorily in the Northwest. They are of value chiefly as breeding stocks.

6. *Golden.*—The golden group is represented by three varieties obtained from local sources in the Northwest. The flowers are large and white with blue veins, and the seed is golden to Isabella color,

varying in degree of clearness with climatic conditions. This flax probably was originally imported from Japan and is grown in limited areas in Montana, North Dakota, and Alberta. C. I. No. 23 is a late flax with numerous heavy, prostrate basal branches. C. I. No. 25 has a tendency to more erect growth, but usually yields less than C. I. No. 23. These strains yield well, but do not average as high as the European seed-flax varieties. Their large golden seeds have a high oil content and are in good demand in the linseed trade when an occasional car comes to market. Their mediocre yielding capacity and short prostrate growth eliminate them in their present form from the serious consideration of flax growers.

7. *Chinese Turkestan.*—Numerous importations from Turkestan and Chosen (Korea) have been grown. All are similar. They are tall, with numerous basal branches, and are very late in maturing. The seeds are relatively small, but rather rich in oil. One type has blue flowers and brown seeds and another has wavy white flowers and white seeds. C. I. No. 43, the only one on which data are reported here, is a blue-flowered brown-seeded form. This matured a fair crop in the three seasons for which data are here reported, but it was always one of the last varieties to be harvested and then usually was harvested before it was ripe. This variety can be grown commercially only when early sowing is possible, and its yield does not commend it.

8. *Abyssinian.*—Abyssinian varieties are not at all adapted to conditions in the Northwestern States. They seldom attain a height of over 18 inches and under field or adverse seasonal conditions produce their crop on stalks ranging from 3 to 10 inches in height. Figure 3 shows one variety of Abyssinian (C. I. No. 38) and one of Indian (C. I. No. 20) flax grown in field plats at Mandan in 1915. Although the season was very favorable, these varieties were too short to be cut satisfactorily with a binder. The stems of Abyssinian varieties are very slender and produce from four to twelve basal branches, which are fairly erect. The varieties are early, but have small seeds, yield poorly, and are not very rich in oil when grown under semiarid conditions. The flowers are always blue, but C. I. No. 36 is a white-seeded variety. White seeds were originally present in all of the importations, but by selection have been eliminated. This is the only example so far noted of a commercial flax variety with blue flowers and white seeds. Many such strains have been produced, however, by hybridization.

9. *Indian.*—The Indian varieties are of importance because much seed is imported from India for crushing purposes. The imported seed is large, with a high oil content, and linseed crushers on various occasions have distributed small quantities of the seed for growing in

commercial tests. Under northwestern conditions a large seed is produced, but the oil content is not high. The varieties are all as short or shorter than the Abyssinian strains, but with a coarser stem, which produces normally about four basal branches. The yields recorded are slightly to materially poorer than those of the Abyssinian varieties. Blue-flowered brown-seeded and white-flowered golden-seeded varieties have both been obtained from India and are included in the data here reported. Hoshangabad (C. I. No. 40), a white-flowered golden-seeded strain, produces seed of low viability, and it is seldom, if ever, that a good stand is obtained. This variety is practically identical with Burbank flax, recently advertised as a flax with wonderful possibilities and sold in small quantities at exorbitant prices. In 1915 the few plants that were produced were seriously injured by flax rust, and the general performance of this variety has always been inferior to that of the other Indian varieties. None are adapted to our northern conditions.

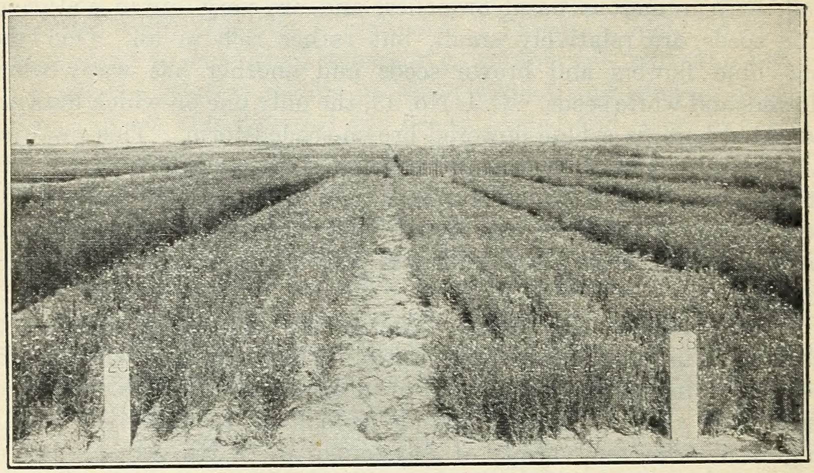

FIG. 3.—Indian (C. I. No. 20) and Abyssinian (C. I. No. 38) flax varieties grown in plat experiments at the Northern Great Plains Field Station, Mandan, N. Dak., in 1915. Note the short growth of these varieties as compared with the Russian flax at the extreme left.

10. *Egyptian.*—The two varieties listed in the Egyptian group are included simply because they are so distinct from any other form noted. The plants are short, with slender unbranched stems. Few bolls are produced per plant, and these capsules are so firm that much force is required to crush them in shelling the seed. Under ordinary conditions of thrashing, the bolls readily fall from the pedicels but remain intact unthrashed. The vegetative growth is so distinct that these varieties could probably be classed as a separate species. The seeds are not small but are very flat, of a characteristic drab color, and have a very low oil content. These varieties are not suited in any way to northwestern conditions.

SUMMARY.

European seed-flax varieties have proved superior to others for the conditions obtaining in the semiarid sections of the North-Central States. The true seed types rather than the short-fiber types are most productive. In the experiments at Mandan the Reserve (C. I. No. 19), Damont (C. I. No. 3), Frontier (C. I. No. 17), and North Dakota Resistant No. 52 varieties have yielded most and are the best known and most widely distributed varieties in this group.

North Dakota Resistant No. 114, while one of the two varieties significantly low in yield in this experiment, is the only variety which possesses superior resistance to flax wilt (*Fusarium lini*). It is not particularly adapted to semiarid conditions, but is recommended for the more humid sections of the Dakotas and Minnesota where flax is grown in rotation with other crops on old land.

Nursery experiments indicate that favorable results can not be expected from new importations in comparison with acclimated seed, particularly if selected domestic strains can be procured. Russian and northern European strains which have undergone natural or scientific selection toward a high seed-producing type are those best adapted for semiarid conditions in the Northwest. Commercial growers should not risk large acreages with Argentine seed, and the growing of Indian, Abyssinian, or south European seed in this area can only result in total failure.

If the preparation of the land has been thorough and a good seed bed is obtained, 20 pounds of flax to the acre seems to be a sufficiently heavy rate of seeding. Heavier seeding may be preferable under certain conditions, such as a seed bed so dry that germination is uncertain. The results obtained do not indicate much advantage in heavier seeding, however, and the high price of seed flax discourages the practice.

Early seeding is recommended on breaking. The land should not be left to dry out after the seed bed is prepared. It is desirable to follow the plow, disk harrow, or packer immediately with the drill if breaking is done in the spring. Land backset the previous fall should be disked before seeding in order to kill weed growth and improve the seed bed. The best results can be expected from seedings made from May 1 to June 10. A rapid decrease in yield from sowings made after June 10 can be expected.

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